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Self-assembled quasi-1D and 2D nanostructures of fullerenes on silicon

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When C_{60} fullerenes adsorb onto a solid crystal surface, their self-assembly is known to follow one of a few typical scenarios which choice is controlled by the competition between the C_{60}-substrate and C_{60}-C_{60} interactions. When C_{60} fullerenes are strongly bonded to a substrate, in the most cases fullerenes adsorb randomly at the surface (in particular, due to abundance of various adsorption sites with close binding energies) and the growing C_{60} layers are typically lacking a well-defined ordering. When the C_{60}-C_{60} interaction prevails, adsorbed fullerenes self-assemble into the close-packed hexagonal C_{60} arrays with C_{60}-C_{60} separation of ~10 Å, close to that in a bulk fullerite.

Using metal-silicon surface reconstructions (i.e., silicon surfaces covered with monoatomic and submonoatomic layers of metals) as a template for the overgrowth of C_{60} layers, one can have growth modes which do not follow the above scenarios. As a result, unusual ordered C_{60} nanostructures can be fabricated. The C_{60} layers grown on Tl-adsorbed Si(111)5×2-Au and Si(111) surfaces, covered by monolayers of metals, Tl or Pb, as well as their Tl-Pb compound, present such examples.

Si(111)5×2-Au surface comprises a quasi-one-dimensional surface reconstruction consisting of Au stripes mediated by honeycomb Si chains. One could expect that this surface might be a suitable template for growing quasi-one-dimensional C_{60} nanostructures. However intact Si(111)5×2-Au surface has been found to produce a poor template effect on the overgrown C_{60} layers which have a close-packed-like structure without distinct ordering. In contrast, the C_{60} layers grown on the Tl-adsorbed Si(111)5×2-Au surface, where Tl atoms occupy various adsorption sites on the honeycomb Si chains, have a well-ordered quasi-one-dimensional structure consisting of straight C_{60} chains. The C_{60}-C_{60} spacing within the chains of ~12 Å that is ~3.2 a_0 (where, a_0 is the lattice constant of Si(111) surface) reflects the peculiarity of the C_{60}-C_{60} intermolecular interaction on the Tl-adsorbed Si(111)5×2-Au surface.

In the C_{60}/Tl/Si(111), C_{60}/Tl/Ge(111), C_{60}/Pb/Si(111) and C_{60}/(Tl, Pb)/Si(111) systems, a family of the exotic 2D C_{60}-metal nanostructures has been discovered. We named these nanostructures the `trilliumenes' since their common basic building block is the four- $C_{60}$ cluster (`trilliumon') which shape is reminiscent of the three-petal flower called `white trillium'. Various stacking of trilliumons produces various 2D ordered nanostructures, the `trilliumenes'. The periodicity of the trilliumene structure is $\sqrt{57}\times\sqrt{57}$-R±6.5° for the C_{60}/Tl/Si(111) system, $\sqrt{37}\times\sqrt{37}$-R±25.2° for the C_{60}/Tl/Ge(111) system and $\sqrt{21}\times\sqrt{21}$-R±10.9° for the C_{60}/Pb/Si(111) and C_{60}/(Tl, Pb)/Si(111) systems. Remarkably that all metal media triggering formation of the trilliumenes on Si(111) surface, i.e. double-atomic Tl layer and single-atomic Pb layer and Tl-Pb compound, have recently been proved to be 2D superconductors. In this respect, the trilliumenes show promise to be 2D nanostructured superconductors, which properties are awaiting their exploration.

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